PROCEEDINGS OF SCIENCE

Exotic diboson searches in the $\ell \nu qq$ final state using proton-proton collisions data at $\sqrt{s} = 13$ TeV collected with the ATLAS detector.

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Analyses searching for diboson resonances are very powerful tools to investigate many beyond the Standard Model scenarios such as extension of the Higgs sector, Heavy Vector triplets (W' and Z') or excited states of Gravitons. These searches exploit many decay channels of the two bosons allowing to select topologies with varied signal to background ratios and statistics. Among these searches the one looking for WW/WZ in the semileptonic final state finds a compromise between the high signal statistics allowed by the high branching ratio of the hadronic decay of the gauge boson while profiting of the good trigger and analysis signature of the lepton, decay product of the second gauge boson. The WW/WZ search for TeV scale resonances in the $\ell \nu qq$ channel with 36.1 fb^{-1} of data collected with the ATLAS detector at $\sqrt{s} = 13$ TeV will be detailed. No significant excess is observed in data with respect to the Standard Model backgrounds. Limits on the production cross section are set for various benchmark scenarios.

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PoS(EPS-HEP2017)683

1. Introduction

Searches for new resonances in the diboson final state can be a very powerful tool to find new hints on new physics Beyond the Standard Model (BSM). Indeed such resonances arise in a wide variety of models such as Extended Gauge Models [1], Warped Extra Dimensions [2], Technicolor models [3], Extra/Composite Higgs [4, 5]. The search carried out by the ATLAS Collaboration in the $WV \rightarrow \ell\nu qq$ final state [6] can be sensitive both to neutral and charged resonances exploiting the two final states $W^{\pm}W^{\mp}$ and $W^{\pm}Z$. The latest results for this analysis are based on the 2015+2016 data sample at $\sqrt{s} = 13$ TeV collected with the ATLAS detector [7] at $\sqrt{s} = 13$ TeV and corresponding to an integrated luminosity of 36.1 fb^{-1}.

2. Theoretical models

Two signal models are used to optimize the event selection, assess the sensitivity of the search and evaluate the cross-section limits: the Randall-Sundrum (RS) and the Heavy Vector Triplet (HVT) models. The Randall-Sundrum model introduces a warped extra dimension to solve the hierarchy problem. It predicts the existence of various new particles among which there are excited states of the bulk graviton that appear as spin-2 neutral particles with masses of the order of few TeV. The coupling of the bulk graviton to Standard Model particles is characterized by $\frac{\kappa}{\overline{M}_P}$ where κ is a warp factor, and $\overline{M}_P$ is the reduced Plank mass: in the case of the present analysis $\frac{\kappa}{\overline{M}_P} = 1$. Instead, the HVT model envisages the presence of three additional spin-1 particles degenerated in mass: a charged particle and its antiparticle, $W'^{\pm}$ and a neutral particle Z'. This triplet arises in a variety of models therefore benchmark models have been generated adopting a parametrized HVT Lagrangian. In this Lagrangian the coupling between the gauge boson and the HVT (g_H) is considered as a parameter of the model. Two values of the coupling g_H are tested: $g_H = 1$ (Model A) favours coupling to fermions, $g_H = 3$ (Model B), favoring coupling to SM bosons.

3. Event selection

Events are required to contain exactly one lepton $\ell = \mu, e$ and large missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) accounting for the presence of a neutrino coming from the leptonic decay of a W boson. The presence of a lepton candidate or of large $E_{\mathrm{T}}^{\mathrm{miss}}$ is also used at trigger level for candidate $e\nu qq$ and $\mu\nu qq$ events respectively. This allows to maximise the signal acceptance while maintaining a low background contamination. The selection of large $E_{\mathrm{T}}^{\mathrm{miss}}$ events also allows to reduce the QCD multi-jet background. Information on the longitudinal component of the neutrino momentum is recovered imposing $M_{\ell\nu} = M_W$. The hadronically decaying boson is traditionally selected requiring the presence of two anti-k_t jets with distance parameter $R = 0.4$. The requirement of two separate jets is responsible for a drop in efficiency at high boson transverse momentum ($p_{\mathrm{T}}^{\mathrm{V}}$). This is expected from the simplified relation that relates the decay products separation (ΔR) to $p_{\mathrm{T}}^{\mathrm{V}}$; $\Delta R \approx \frac{2\times M_V}{p_{\mathrm{T}}{}^{V}}$ where M_V is the mass of the decaying boson. To recover the efficiency at high p_{T}^{V} a second topology is considered where the two quarks coming from the boson decay are reconstructed as a single large-R jet (anti-k_t, $R = 1.0$). In the merged regime, the large cone size used to reconstruct the boson decay products gives rise to a large contamination by soft particles and, this effect is mitigated by using a so-called trimming technique[1]. Once trimming is applied, boson identification techniques [8] can be applied to the large-R jet to identify jets consistent with a two-prong substructure. The boson tagger adopted in the present analysis is named D_2 and is used to divide events in two categories: high and low purity categories. The two categories correspond to tagging working point providing 50% and 80% signal selection efficiency. After those requirements are applied events are further categorised based on their production channel. Events containing two additional jets with ($m_{jj}^{tag} > 770$ GeV and $\Delta\eta_{jj}^{tag} > 4.7$) are considered as produced through Vector Boson Fusion (VBF), while events failing VBF selection are considered as produced through Drell-Yan (DY) processes.

4. Analysis strategy: signal and control regions

The main Standard Model processes that contribute to the background are W+jets, $t\bar{t}$, single-top, Z+jets and Standard Model diboson. The compatibility between the diboson mass distribution for the background processes and that one observed for data is used to evaluate the evidence for new particles or to set a limit on the cross-section times the branching ratio. The expected mass distribution for processes giving a small contribution to the total expected background is estimated completely from simulated samples. The mass distribution for W+jets and $t\bar{t}$ is instead evaluated using both simulated data to asses the expected distribution shape and data control region to obtain the distribution normalization. Therefore for each category described in Section 3 a signal region is defined with two requirements:

1. M_V **mass**: the candidate hadronically decaying gauge boson is required to have a mass compatible with the one expected for a W boson for $W^{\pm}W^{\mp}$ selection or Z boson for $W^{\pm}Z$ selection;
2. **b-veto**: the event is required to contain zero b-tagged anti-k_t 0.4 jets excluding the ones used as candidate hadronically decaying gauge boson.

The W+jets control region is obtained inverting the M_V mass requirement while the $t\bar{t}$ control region is obtained requiring the event to fail the b-veto. Once events are split in signal and control regions the background normalization is obtained with a simultaneous maximum-likelihood fit in signal and control regions over the $\ell\nu qq$ mass spectrum. A likelihood function is defined as the product of Poissonian probabilities for each mass bin. Systematic uncertainties are introduced as constrained nuisance parameters following the method presented in Reference [9]. The main systematic uncertainties are due to the D2 modelling and to the W+jets process normalization.

5. Results

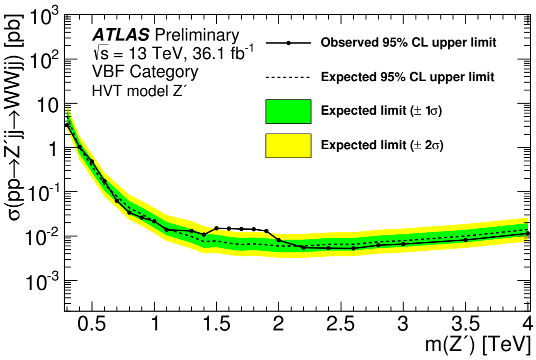
The exclusion limits evaluated using the modified frequentist method CL_s [10], and profile-likelihood statistic test, are evaluated on the binned $m_{\ell\nu qq}$ distributions. Limits on cross section times branching ratio extracted from the Drell-Yan categories are summarised in Table 1. In the case of VBF categories no exclusion has been attempted due to the very low statistic, upper limits on cross section times branching ratio for VBF categories are shown in Figure 1.

[1]The trimming algorithm used in these analyses uses k_t sub-jets with a radius parameter of 0.2 and a p_{T} cut of 5%

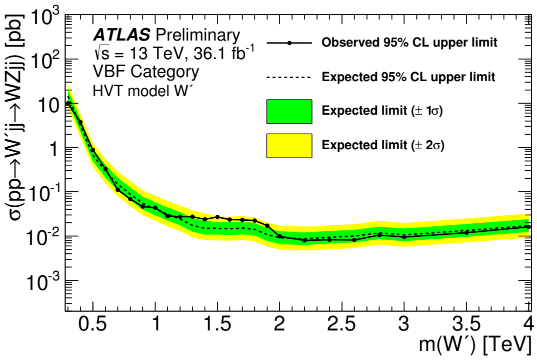
PoS(EPS-HEP2017)683

Observed (expected) exclusion limit at 95% CL	HVT Model-A $g_H = 1$ M_X [GeV]	HVT Model-B $g_H = 3$ M_X [GeV]	RS G^* $\frac{\kappa}{M_P} = 1$ M_{G^*} [GeV]
Drell-Yan WW	< 2750 (2840)	< 3090 (3230)	< 1760 (1750)
Drell-Yan WZ	< 2820 (2890)	< 2980 (3240)	-

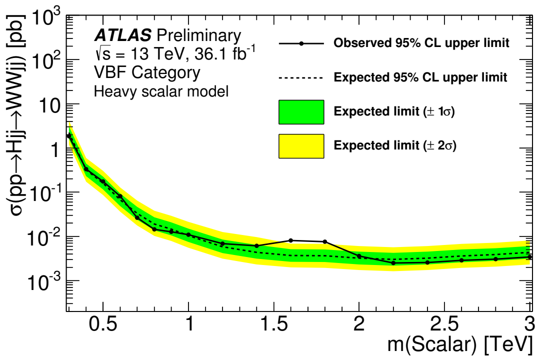
Table 1: Summary of observed and expected exclusion limits at 95% CL for Drell-Yan categories [6].



(a)



(b)



(c)

Figure 1: Observed and expected cross section upper limits at the 95% confidence level for WV production in the VBF category [6]. Interpretations for HVT $W^{\pm}W^{\mp}$ (a), HVT $W^{\pm}Z$ (b) and scalar $W^{\pm}W^{\mp}$ (c) signals produced via VBF are shown.

6. Conclusions

A summary of the search for new resonances in the semileptonic diboson final states $\ell\nu qq$ performed using 36.1 fb^{-1} of pp collision data collected at a center-of-mass energy of $\sqrt{s} = 13$ TeV by the ATLAS detector was presented. The new event topologies exploited in the analysis and the higher available luminosity allowed to raise the limits set in the previous publication [11]. No significant deviation with respect to the Standard Model prediction was found. The presence of

HVT $Z^{'}$ Model A (B) produced via gluon-gluon fusion is excluded at 95% CL for masses below 2750 (3090) GeV while the charged component HVT $W^{'\pm}$ Model A (B) is excluded for masses below 2820 (2980) GeV. For the Randall-Sundrum G_{KK} signals with $\kappa/\overline{M}_P = 1.0$ produced via gluon-gluon fusion, masses below 1760 GeV are excluded at 95% CL, thus improving the previous result of roughly 700 GeV.

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